魚類における無機質の要求に関する研究 I

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Mineral Requirements in Fish—I
Effects of Dietary Salt-Mixture Levels on Growth, Mortality, and Body Composition in Rainbow Trout and Carp

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Diets containing graded levels of salt-mixture (McCOLLUM's salt-mixture no. 185 plus trace elements) were given to young rainbow trout and carp for 50 days.

Dietary levels of the salt-mixture exerted a strong influence on growth and mortality in rainbow trout and on growth in carp. Rainbow trout were more sensitive to the lack of the dietary salt-mixture than carp. The diet deficient in the salt-mixture resulted in retarded growth, high mortality, anemia and malformation of the head in rainbow trout.

The optimal content of the salt-mixture in the diet was proven to be 4 to 5% for both species under the present experimental conditions.

The mineral requirements in fish appear to be very complicated since metabolism and nutrition of minerals are closely related not only to those present in the diet but also to those dissolved in the surrounding water.[1-4] Recently, however, it has been reported that dietary minerals have enormous effects on growth, survival and malformation in chinook salmon,[5] carp,[6,7] eel,[8] channel catfish,[9] red sea bream[10] and yellow-tail.[11]

The present studies were undertaken to investigate the effects of dietary salt-mixture levels on growth, mortality and body composition in young rainbow trout (*Salmo gairdneri irideus*) and carp (*Cyprinus carpio*). Deformity caused by the lack of dietary minerals was also examined. Addition of the salt-mixture at dietary levels of 4 to 5% was found to be optimal for growth and prevention of deformity in both species when casein was used as the sole dietary protein.

Materials and Methods

McCOLLUM's salt-mixture no. 185[12] fortified with trace elements[13] was used for the experiments with rainbow trout and carp. Composition of the experimental diets is shown in Table 1. The salt-mixture levels in these diets were adjusted by proportionately altering the cellulose content in the basal diet. The basal diet lacking the salt-mixture contained 0.32% phosphorus and 0.015% calcium, which originate from casein. Diets were given in dry, pellet form.

Rainbow trout averaging 1.1 g and carp averaging 2.0 g in body weight were used. Fish were previously fed on a commercial diet and the casein-diet containing 4% of the

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Table 1. Composition of the experimental diet for young rainbow trout and carp

Casein (vitamin-free)	45%
α-Starch	20
Dextrin	20
Soybean oil	2
Cod liver oil	3
Vitamin mixture*1	2
Cellulose	8–0
Salt mixture*2	0–8

*1 Composition is the same as that reported previously.[16]
*2 McCollum's salt mixture no. 185 plus trace elements.[13]

salt-mixture and acclimatized to the experimental conditions.

The feeding trials which lasted 50 days were conducted on diets containing 0, 1, 2 and 4% of the salt-mixture for rainbow trout and on diets containing 0, 1, 2, 4, 6 and 8% of the mixture for carp, using aquaria with dimensions of $30 \times 45 \times 30$ cm under conditions of aerated, running dechlorinated city water (15 liters/hr). Water temperature fluctuated within the range 14 to 18°C in the trial for rainbow trout and 18 to 25°C in the trial for carp. Fish were fed 3 times daily, 6 days a week on a rigid schedule.

Calcium, magnesium and manganese in diets and fish body were determined with a Hitachi model 208 atomic absorption spectrophotometer after wet digestion of samples in a nitric-perchloric acid mixture. The determination of phosphorus was made by the method of Fiske-Subbarow[14] and iron by the method of Barkan and Walker.[15]

The experimental rearing water contained 15 to 20 ppm calcium, 3 to 4 ppm magnesium and 0.002 ppm phosphorus.

After 50 days of feeding, blood was collected from the caudal artery, and erythrocyte number was counted in rainbow trout and hemoglobin content was determined by the cyanmethemoglobin method in carp.

Results and Discussion

Growth, mortality, and efficiency of food utilization The results of the feeding trials with rainbow trout and carp are shown in Table 2 and Fig. 1. The dietary salt-mixture levels exerted a strong influence on growth and mortality in rainbow trout and on growth in carp. However, growth responses to the dietary salt-mixture levels were somewhat different between rainbow trout and carp as shown in Fig. 1. The rainbow trout were more sensitive to the lack of the salt-mixture in the diet than carp. The diet deficient in the salt-mixture resulted in retarded growth, high mortality and low feed efficiency in rainbow trout, while in carp only a slight diminution of weight gain was observed. The growth rate increased as the salt-mixture level was increased to 4% in both species but was suppressed at higher levels in carp. This may be due to a diminution in the amount of

Table 2. Results of 50-day feeding trials with diets containing different levels of the salt-mixture*1

	Salt-mixture in diet	No. of fish	Average weight		weight gain	Mortality	Feed efficiency*2
			at start	at end			
	%		g	g	%	%	
Rainbow trout	0	60	1.16	2.84	144	11.7	0.83
	0	60	1.15	2.93	154	10.0	0.81
	1	60	1.17	4.62	295	0	0.92
	2	60	1.14	4.79	320	0	1.04
	4	60	1.16	4.96	327	0	1.09
Carp	0	40	1.98	4.59	131	0	0.92
	1	40	2.00	4.88	144	0	0.95
	2	40	1.99	4.89	146	0	0.95
	4	40	1.99	5.09	156	0	0.99
	6	40	2.05	5.09	148	0	1.04
	8	40	2.08	4.70	126	0	0.96

*1 Water temperature fluctuated from 14 to 18°C in feeding of rainbow trout and from 18 to 25°C in feeding of carp.
*2 g gain/ g feed.

diet consumed by carp, since there was no appreciable difference in feed efficiency among the diffrent diets.

Dificiency symptoms Rainbow trout which were fed on the diet lacking the salt-mixture lost their appetite and became sluggish after 2 weeks. After 3 to 4 weeks, some of the fish exhibited convulsions which finally terminated in death. At the end of the experiment, most of the surviving fish showed scoliosis or lordosis. The malformation of head which was characterized by a round and shortened snout developed in almost all the fish receiving basal diet lacking the salt-mixture (Fig. 2). This deficiency sign may arise from an abnormality in the formation of cartilage around the skull. In contrast to rainbow trout, overt signs of the deficiency were not observed in carp.

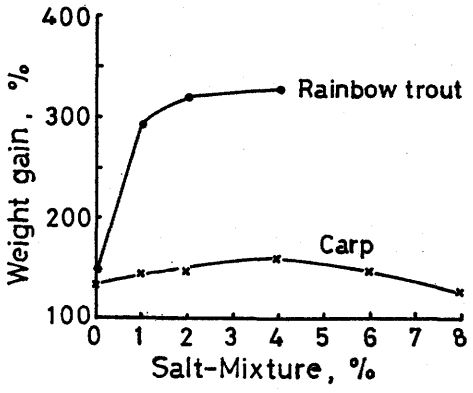

Fig. 1. Relationship between dietary salt-mixture levels and growth of fish.

Erythrocyte count and hemoglobin content As shown in Table 3, the erythrocyte counts were greatly affected by the dietary salt-mixture levels in rainbow trout. Those fish which received the salt-mixture less than 4% displayed an anemic condition. This result may be attributed, in part, to the lack of iron intake. In contrast, no distinct differences in hemoglobin content were observed among carp which received different leveles of salt-mixture. These results may be related to the differences observed in the iron content of whole body of the two species (Table 5).

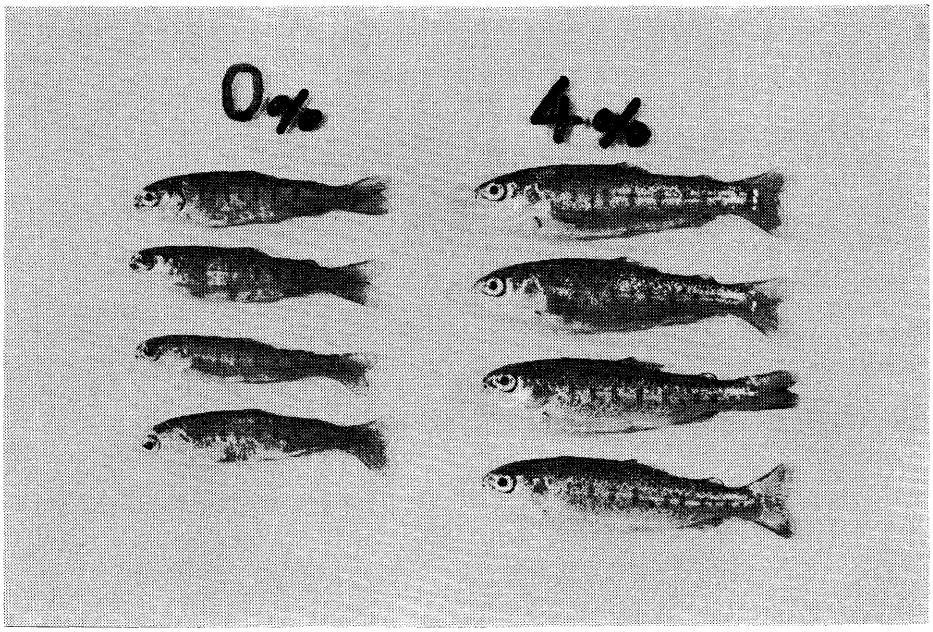

Fig. 2. Photograph showing the rainbow trout fed a diet deficient in salt-mixture (0%) and the fish fed a diet containing 4% salt-mixture (4%). The malformation of the head of the deficient fish is noticeable.

Table 3. Effects of dietary levels of salt-mixture on erythrocyte counts (rainbow trout.) and hemoglobin content (carp)

Salt-mixture content	Erythrocyte* (rainbow trout)	Hemoglobin* (carp)
%	$\times 10^4/mm^3$	g/100 m*l*
0	69.2± 9.8	8.1±0.66
1	87.1±18.5	9.4±0.97
2	101.1±18.3	8.4±0.76
4	105.1± 7.2	7.5±0.75
6		7.9±0.53
8		9.1±0.36

* Each value is an average of 5 observations.

Chemical composition of the whole body The chemical composition of the whole body of each experimental group after 50-day feeding trials is shown in Table 4. In rainbow trout, the fish which were fed on a diet lacking the salt-mixture contained less lipid and more water than those of the supplemented groups. There were no measurable differences in ash and protein contents. In carp, the ash content increased with increase in the dietary salt-mixture level, but no significant differences could be seen in moisture, lipid and protein contents.

Table 5 indicates the mineral composition of the whole body in each experimental group after 50 days of feeding. The elements which were evidently affected by the dietary salt-mixture levels were magnesium and iron in rainbow trout, and calcium, phosphorus,

Table 4. Effect of dietary salt-mixture levels on chemical composition of the whole body (on wet basis)

Salt-mixture in diet	Rainbow trout				Carp			
	Moisture	Ash	Lipid	Protein	Moisture	Ash	Lipid	Protein
%	%	%	%	%	%	%	%	%
0	79.1	2.34	4.88	14.9	79.4	2.41	4.69	14.1
1	78.2	2.13	5.43	15.5	78.0	2.46	4.73	14.6
2	77.6	2.40	6.01	15.4	78.5	2.58	4.98	15.5
4	77.8	2.49	5.33	15.4	79.0	2.77	4.17	14.1
6					79.2	2.91	4.54	14.2
8					77.8	3.01	4.76	14.6

Table 5. Effect of dietary salt-mixture levels on mineral composition of the whole body (on wet basis)*

Salt-mixture in diet	Rainbow trout					Carp				
	Ca	P	Mg	Fe	Mn	Ca	P	Mg	Fe	Mn
%	%	%	mg/100g	mg/100g	mg/100g	%	%	mg/100g	mg/100g	mg/100g
0	0.49	0.30	17	4.8	0.072	0.56	0.42	21	2.2	0.062
1	0.48	0.33	22	9.9	0.15	0.66	0.46	24	3.7	0.087
2	0.48	0.37	25	10.5	0.14	0.73	0.47	26	3.0	0.065
4	0.52	0.37	28	11.5	0.091	0.76	0.56	30	3.1	0.094
6						0.77	0.58	30	3.3	0.080
8						0.80	0.64	32	3.6	0.095

* Each value is an average of 5 determinations.

and magnesium in carp. It is noteworthy that the iron content is greatly different between the two species. The manganese content was somewhat lowered in the fish receiving the diet lacking salt-mixture.

Changes in the amounts of ash and certain minerals The amounts of minerals in the fish body increased during the experiment even in those fish which received a diet containing no salt-mixture. This fact may be attributable to minerals in casein and rearing water. The increased amounts of ash, calcium, phosphorus and magnesium in the whole body of each group after 50-day experimental period are shown in Fig. 3. Since the analyses of calcium, phosphorus and magnesium were not made at start for rainbow trout, only the change in the ash content is shown in the figure.

In carp, phosphorus and magnesium reached nearly constant values at a dietary salt-mixture level of 4%. Calcium and ash attained highest values at a salt-mixture content of 4 to 5% and then decreased gradually with increase in the salt-mixture content. The ash content of the body of rainbow trout appears to reach the highest value at about 4% level of the salt-mixture.

Optimal dietary level of the salt-mixture The present studies have demonstrated that the addition of a salt-mixture to the diet is essential in order to meet the mineral requirement of fish. The utilization by fish of dissolved minerals in water for satisfying

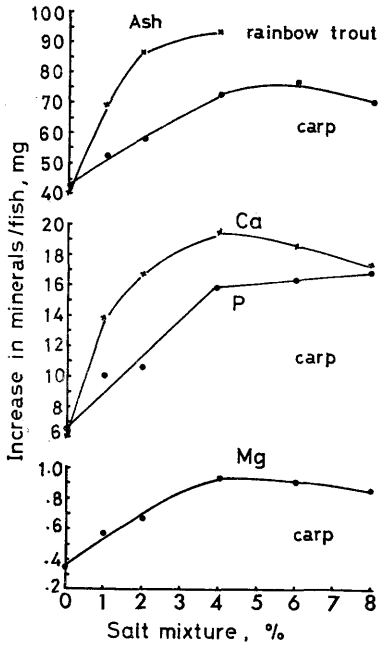

Fig. 3. Relationship between dietary salt-mixture levels and increase in amounts of ash, calcium, phosphorus and magnesium in the body.

their nutritional requirement appears to be limitted to some specific elements. Judging from the experimental results, it is concluded that the optimal dietary level of the salt-mixture is 4 to 5% both in rainbow trout and carp when McCollum's salt-mixture no. 185 fortified with trace elements was used under the present experimental conditions. At dietary levels below 4%, it is considered that some minerals are insufficient to meet the nutritional requirement of the fish. At dietary levels higher than 5%, food consumption decreased in carp.

It should be mentioned here, however, that the salt-mixture used in the present studies is one formulated for the purpose of the feeding young rats. Further investigations are necessary to elucidate the composition of minerals which fulfils the requirement of fish.

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